Estimation of Stock Biomass of Anchovy on Continental Shelf off Argentina by Echo Sounder*1

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In order to estimate the stock biomasses of Argentine anchovy, survey by a regular echo sounder and operation of a mid-water trawl were made. This study was conducted by R/V Shinkai-Maru in the spring (1st cruise) and summer (2nd cruise) seasons of 1978. The survey areas were about 10×10^4 mile^2 shallower than 100 m on the continental shelf off Argentina, and were divided into about 100 small blocks. Echo-sounding lines were set on the diagonal lines of the blocks. The total distances covered were about 5×10^3 miles.

Counting of echoes by sounder and the results of catches obtained by simultaneous fishing operations were combined and analyzed for estimation. The stock biomass index and the density index in each block, and the density of anchovy for each operation were calculated. Using these values, the stock biomasses of anchovy were estimated by two methods. In the 1st cruise, the estimates were 368.4×10^4 tons by equation (4) and 445.2×10^4 tons by eqution (5), and the 2nd cruise, 984.4×10^4 tons and 797.7×10^4 tons.

Counting of echoes recorded by an echo sounder and the results of mid-water trawl operations were combined and analyzed to estimate the relative abundance and the stock biomasses of Argentine anchovy, *Engraulis anchoita* (Argentine name, Anchoita) on the continental shelf off Argentina.

On the distributions of marine pelagic fishes and the estimation of stock biomasses by means of counting echoes recorded by an echo sounder, the reports were made by many authors (Balls, 1948; Cushing, 1952; Yokota, 1953; Yokota et al., 1953; Kamiura, 1957, 1958a, 1958b, 1966; Nozu, 1965; Asami and Kamiura, 1966; Aoyama and Mimoto, 1970; Azeta, 1974; Kovalev et al., 1977; Klochkov et al., 1977; Ogawa and Nakahara, 1978). Also with regard to inland water, several reports were published on the same topic (Kuroki and Chūman, 1953; Shiraishi and Furuta, 1963; Tanaka, 1978).

In the Argentine waters, surveys by echo sounder were made during the United Nations Development Project, carried on from July 1966 to June 1974 (Aasen, 1967; Aasen and Castello, 1968a, 1968b; Castello and Gagliardi, 1968a, 1968b; Brandhorst and Castello, 1971, 1972; Brandhorst et al., 1971a, 1971b, 1972). Fishery Agency of Japan (1971), Burczynski and Wrzesinski (1974) and Wrzesinski (1975) reported the survey in the Argentine waters, but any large scale survey has not been made afterwards.

If the estimation of stock biomass is required in a short period of time, the acoustic survey is one of the most suitable method. In recent years, an echo sounder with integrator is frequently used to estimate the fish biomass (Dowd, 1967; Thorne and Lahore, 1969; Midttum and Nakken, 1971; Shibata

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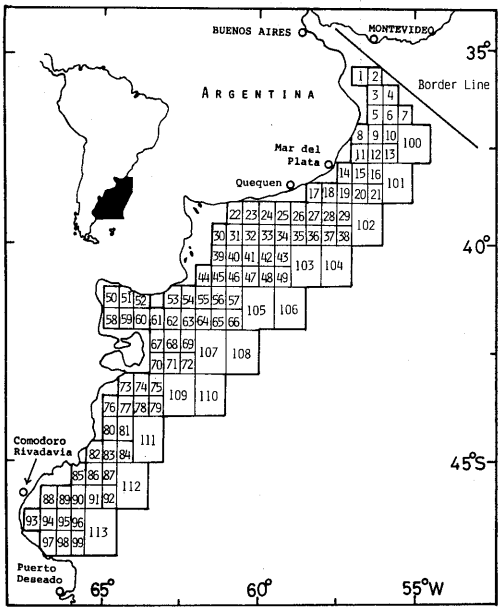

Fig. 1. Map showing research area and blocks covered in the 1st cruise. Numerals in figure denote block number.

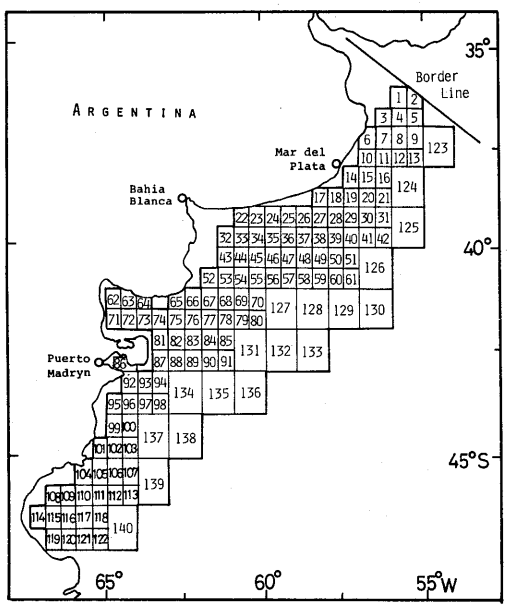

Fig. 2. Blocks covered in the 2nd cruise. Numerals in figure denote block number.

et al., 1971; Mimoto and Aoyama, 1978), but the instruments and measuring methods are not yet established. In this report, counting of echoes recorded by regular echo sounder and the results obtained by simultaneous fishing operations were combined for estimating stock biomasses.

Outline of Survey

The research program was conducted upon the "Agreement for the Performance of Fishery Investigations" between Argentine Republic and Japan Marine Fishery Resource Research Center (JAMARC). This study was operated by R/V Shinkai-Maru (3395 GT). The survey periods were from September 21, 1978 to October 12 (1st cruise, spring) and from November 20 to December 19 (2nd cruise, summer). The echo sounder used was Model MWB-115 made by Kaijo Denki Co. Ltd. (frequency 24 KHz, half angle longitudinal 3° and transverse 6°, paper speed 16 mm/min, pulse generation 45 times/min, depth range 0 to 250 m, wet type), and the transducer was fitted vertically at a depth of 5 m.

The area investigated was from Lat. 35°30′ to 47°S and from Long. 54° to 67°30′W mainly shallower than 100 m on the continental shelf off Argentina, covering 104,112.0 mile² in the 1st cruise and

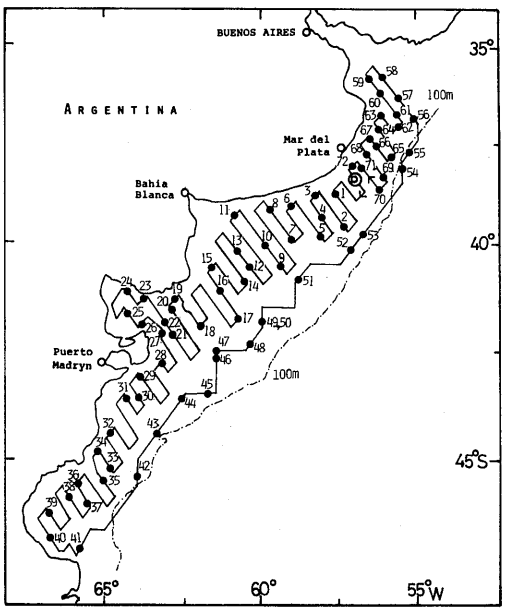

Fig. 3. Course of sounding survey and trawl stations in the 1st cruise. Numerals indicate trawl station number. ◎: the start (the finish) point.

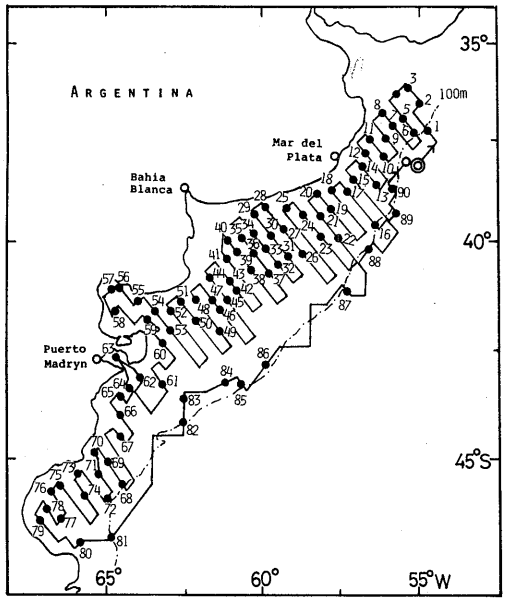

Fig. 4. Course of sounding survey and trawl stations in the 2nd cruise. Numerals indicate trawl station number. ◎: the start point. ○: the finish point.

130,767.7 mile² in the 2nd cruise (Figs. 1 and 2). The survey area was set to cover the entire region where anchovy was expected to be distributed, based on the information obtained in the past. In the 2nd cruise the area was fairly expanded because of a longer survey period. The survey areas were divided into either small blocks of 30′×30′ or large blocks of 1°×1°, as shown in Figs. 1 and 2. In the 1st cruise, 99 small blocks and 14 large blocks were set, and in the 2nd cruise, 122 small blocks and 18 large blocks (the block numbers of both cruises do not coincide with each other). Echo-sounding lines were mostly set on the diagonal lines of the small blocks by about 37.5 miles each on the average, as shown in Figs. 3 and 4. On the offshore side, the eho-sounding lines were set on the large blocks by 26.8 to 108.7 miles each.

The intervals between the sounding lines were about 18.2 miles. On the survey lines, the vessel sailed usally at 12 to 13.5 knots. The total distance covered was 4,547.3 miles in the 1st cruise, and 5,773.6 miles in the 2nd cruise.

In the survey by an echo sounder, it is im-

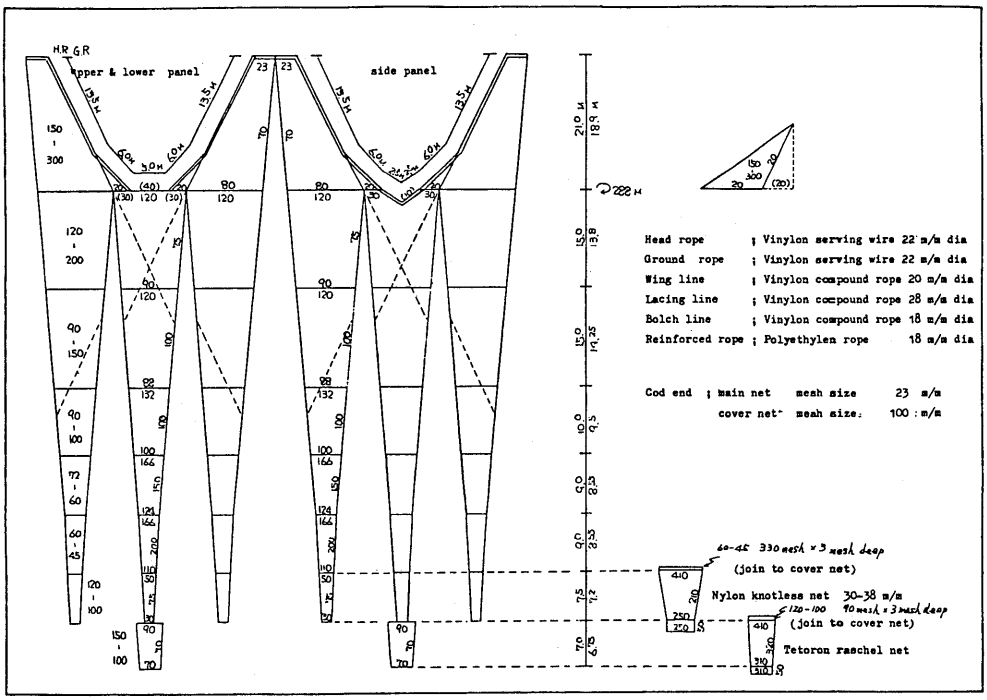

Fig. 5. Design of Shinkai-Maru's mid-water trawl net.

possible to identify fish species and their lengths. Therefore, a mid-water trawl gear (Fig. 5) designed for krill fishing was used 72 times in the 1st cruise and 90 times in the 2nd cruise, to identify fish species and to estimate stock biomasses (Figs. 3 and 4).

Fifty-nine species of fishes were caught by the mid-water trawl operation. Bottom fishes were included in this catch, because some hauls were made just on the sea bottom due to shallower depth or other reasons. In addition, two species of squids and several species of crustacea were caught. A great majority of the catch was anchovy. Since the survey was targeted to anchovy, the information for the other species was not sufficient, but pelagic fishes other than anchovy were presumed to be poor both in the number of species and quantities.

In addition to the biomass survey, biological measurements of anchovy were made as to the fork length, body weight, sex, gonad weight, gonad maturity stage, stomach contents, etc. The mean fork length of anchovy caught ranged from 8.1 ~15.6 cm (1st cruise) and 8.2~15.4 cm (2nd cruise), respectively.

The name of species occurred, catches by species, distribution of main pelagic fishes and biological information of anchovy are shown in JAMARC (1980).

Stock Biomass Index and Density Index

The schooling of anchovy is quite different between nighttime and daytime. They form dense schools in the mid-water (aggregated type) during daytime, but during nighttime they are considerably dispersed in the surface water (dispersed type). According to Aoyama and Mimoto (1970), Japanese anchovy showed the daytime schooling type from one hour and a half before the sunrise to one hour and a half after sunset. In this kind of survey, it is better to restrict the survey time either to daytime or nighttime only. Actually, Yokota (1953), Kamiura (1966) and Aoyama and Mimoto (1970) restricted the survey time only to daytime. However, this survey was made both day and night because the period for survey was limited.

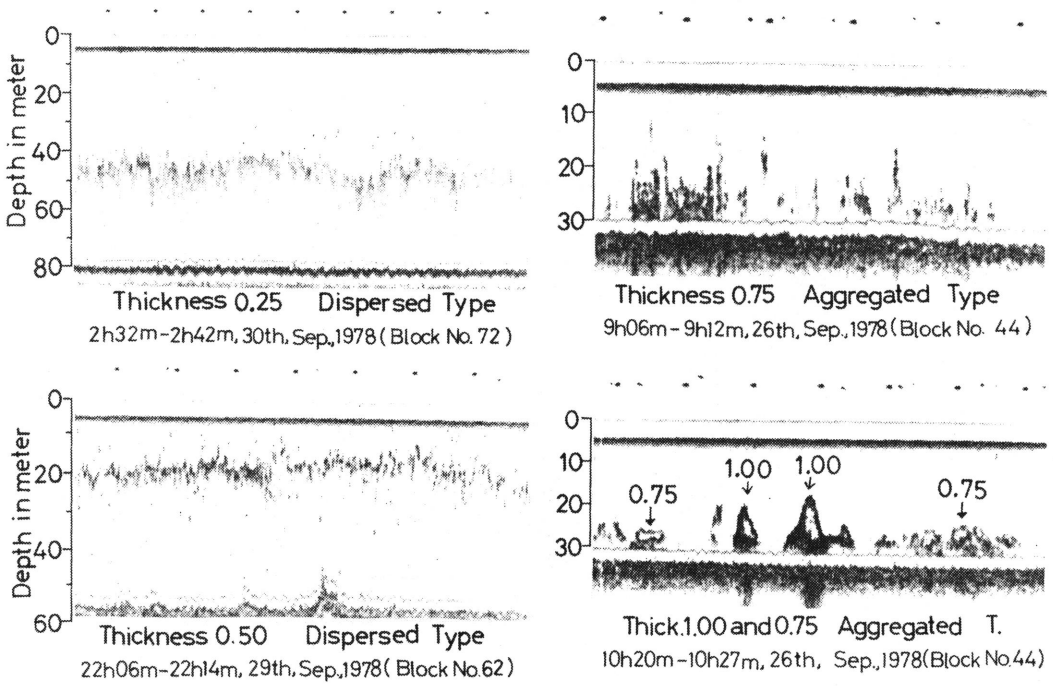

Fig. 6. Typical echoes of anchovy by echo sounder and four classes of echo thickness.

Of all the echoes recorded by an echo sounder during sailing in an average speed of 13 knots (12 to 13.5 knots), the areas (A; mm^2) of those surmised to be echoed by anchovy were measured. The areas were measured by overlapping a transparent section paper on the recorded echoes. In this survey, it was recognized that the density of anchovy is well expressed by the thickness of recorded echo. To lessen the difference between aggregated type in daytime and dispersed type in nighttime, the thicknesses (T) were classified into four classes of I to IV and according to its thickness, the area of each echo recorded was weighted by 0.25, 0.50, 0.75 and 1.00, respectively. Fig. 6 shows examples of each class of thickness judged by the authors' sense of sight. During the survey period the transmission output and reception sensitivity of the echo sounder were kept constant.

The stock biomass index in each block was obtained by the following equation.

$$\text{Stock Biomass Index } (SBI;\ \text{mm}^2) = \sum AT \quad (1)$$

However, since there were some differences between sounding distances of respective blocks, the density indexes were further calculated by the following equation.

$$\text{Density Index } (DI;\ \text{mm}^2/10\ \text{miles}) = SBI\ /\ (\text{Distance}/10) \quad (2)$$

The results are shown in Tables 1 and 2 by cruise. In these tables, sounding distances and survey time by daytime or nighttime are shown together. The DI means the relative index of fish density of each block, and their distributions are summarized in Figs. 7 and 8.

Methods of Trawl Operations

Three or four mid-water hauls were made a day when the echoes were recorded by echo sounder. The vessel trawled the water layer where the echoes were recorded most densely, in order to catch anchovy as many as possible. The mean water depths which the center of the trawl net passes were 30.8 m in case of 1st cruise, and 24.6 m in case of 2nd.

Species caught together with anchovy in the area investigated were jack mackerel, mackerel, Fueguian spratt, Argentinian hake and salpa, plankton and others. Fueguian spratt distributes only in the south beyond the southern margin of the distribution area of anchovy. Argentinian hake, salpa and plankton were generally identified by differences in the form of echo. However, it is difficult to discriminate several pelagic species such as jack mackerel and mackerel from anchovy by the recorded echoes. So, trawling was made in each block in the regions where jack mackerel and mackerel are distributed. Trawl stations were shown in Figs. 3 and 4, but hauling was not always made at the center of each block.

The density of anchovy was calculated for each operation, using equation (3). In this case, the net coefficient was assumed to be 1.0, for nighttime and daytime, therefore, the density might be more or less underestimated.

$$\text{Density (ton/mile}^3) = Y / \left(a \times \frac{b}{60} \times \frac{c}{1852^2}\right) \quad (3)$$

Y: Catch (ton)

a: Hauling speed (3 to 4 knots)

b: Minutes hauled (usually 30 minutes)

c: Area of trawl mouth (m^2)

Catches and densities are given in Tables 1 and 2. In the 1st cruise, anchovy of 19.8 tons were caught, and in the 2nd, 51.9 tons.

Specially during nighttime, the measurement of stock biomass index (SBI) was sometimes very difficult due to salpa and plankton. In blocks where jack mackerel and mackerel were caught together, SBIs calculated from the whole echoes included jack mackerel and mackerel. In this case, SBI of anchovy was estimated from the rates of weight of anchovy to catch caught by mid-water trawling in the block. This value is surmised to contain some errors, and specially noted as H(hard) in the SBI columns of Tables 1 and 2.

In block Nos. 5 and 8 to 12 of the 1st cruise, SBI measurement could not be made because of

Table 1. Stock biomass index, density index, catch and density of anchovy observed in the 1st cruise.

Block No.	Distance (mile)	Time	Stock Biomass Index (mm^2)			Density Index (mm^2/10 miles)	St. No.	Catch (Kg)		Density ($ton/mile^3$)
1	37.5	D	0	H		0	59	0		0
2	40.0	N～D	0	H		0	58	0		0
3	37.5	D	3989.8	H		1063.9	60	1354.2		7789.2
4	40.0	N	4603.0	H		1150.7	57	947.7	S	6276.7
5	37.5	N	1028.5	H	E	274.3	63	247.0		2159.4
6	37.5	N	1867.1	H		497.9	61	582.0		4240.1
7	37.5	N	550.0	H		146.7	56	6.7	F	36.6
8	27.5	N	209.4		E	76.1	67	109.7		599.4
9	37.5	D	654.1	H	E	174.4	64	188.5		1373.3
10	37.5	N	948.3		E	252.9	62	291.5		1991.0
11	37.5	N	994.2		E	265.1	68	286.5	S	2087.3
12	37.5	D～N	3522.0		E	939.2	66	1353.3		7394.4
13	37.5	D	36.0			9.6	65	0	F	0
14	37.5	D～N	4419.7			1178.6	○72	821.5		5985.0
15	37.5	D	293.8			78.3	71	0	T	0
16	37.5	N～D	89.0			23.7	69	0	F	0
17	37.5	D	0			0	3	0		0
18	37.5	N	560.0	H		149.3	1	202.5		1106.5
19	37.5	N	500.0	H		133.3				
20	37.5	D～N	20.0			5.3				
21	37.5	D	90.5			24.1	70	0	F	0
22	37.5	N	0			0	11	0		0
23	37.5	N	0			0				
24	37.5	N	0			0	8	0		0
25	37.5	D	0			0	6	0		0
26	37.5	N～D	0			0				
27	37.5	N	0			0	4	0		0
28	37.5	D	0			0				
29	37.5	N	0			0				
30	37.5	D～N	13.0			3.5				
31	37.5	N	0			0				
32	37.5	D～N	0			0				
33	37.5	N	93.0			24.8				
34	37.5	D	0			0	7	0		0
35	37.5	D	0			0				
36	37.5	N	0			0	5	0		0
37	37.5	N	0			0				
38	37.5	D	0			0	2	0		0
39	37.5	N	514.0	H		137.1				
40	37.5	D	15.0			4.0	13	0.1		0.6
41	37.5	N	0			0				
42	37.5	D	300.0			80.0	10	0.2	F	1.1
43	37.5	N～D	0			0				
44	37.5	D	607.5			162.0	○15	3464.7		30290.1
45	37.5	D	1592.0			424.5				
46	37.5	N	1225.0	H		326.7	14	232.8		1272.0
47	37.5	D	70.0			18.7	12	1.0	F	7.3
48	30.0	D	125.0			8.3				
49	37.5	D	0			0	9	0		0
50	33.5	N	0			0				
51	36.0	D～N	1279.3			355.4	○24	629.8		4588.3
52	37.5	D	149.3			39.8	○23	180.9		1129.6
53	35.5	D	196.0			55.2	○19	227.7		1421.9
54	37.5	N	0			0				
55	37.5	N	1080.0			288.0				
56	37.5	D	110.0			29.3	16	0	SF	0
57	37.5	N	0	H		0				
58	34.5	N	0			0				
59	37.5	N	3.0			0.8	25	0.2		1.5
60	45.0	D	190.0			42.2	○26	607.7		3320.5
61	37.5	D	507.3			135.3	22	20.9	S	126.9
62	37.5	N	767.5	H		204.7	20	0	T	0
63	39.0	D	3045.0			780.8				
64	37.5	D	1000.0			266.7	○18	2937.4		21400.1

Table 1. (continued)—1st cruise.

Block No.	Distance (mile)	Time	Stock Biomass Index (mm^2)		Density Index (mm^2/10 miles)	St. No.	Catch (Kg)		Density (ton/$mile^3$)
65	37.5	N	60.0		16.0				
66	37.5	D～N	219.0		58.4	17	39.0		258.6
67	34.7	D	612.3	H	176.5	27	0.3		1.9
68	37.5	N～D	4503.9		1201.0	21	2412.1		17573.1
69	37.5	N	871.0	H	232.3				
70	37.5	D～N	1910.4	H	509.4	28	489.6		3566.9
71	37.5	D	380.0		101.3				
72	37.5	N	575.0	H	153.3				
73	37.5	D	609.5		162.5				
74	37.5	N～D	1647.6	H	439.4	29	611.9	S	3715.0
75	37.5	N	91.2		24.3				
76	37.5	N	207.5	H	55.3				
77	37.5	D～N	1505.5		401.5	○31	1132.6		6429.7
78	37.5	D	48.0		12.8	30	5.5		40.1
79	37.5	N	0	H	0				
80	37.5	D	65.5		17.5	○32	348.0		2237.0
81	37.5	N	0	H	0				
82	35.4	D～N	30.3		8.6	34	24.9		170.1
83	37.5	D	0		0				
84	37.5	N	0	H	0				
85	37.5	D	0		0	36	0		0
86	33.7	N	0		0	35	0		0
87	37.5	D	0		0	33	0	T	0
88	37.5	N	0		0				
89	37.5	N	0		0	38	0		0
90	37.5	D	0		0	37	0		0
91	37.5	N～D	0		0				
92	37.5	N	0		0				
93	37.5	D	0		0				
94	37.5	N～D	0		0	39	0		0
95	37.5	N	0		0				
96	37.5	D	0		0				
97	35.0	D	0		0	40	0		0
98	35.0	D	0		0				
99	37.5	N	0		0	41	0		0
100	67.5	D	221.5		32.8	55	0	F	0
101	67.5	N～D	0		0	54	0		0
102	67.5	N	0		0	53	0		0
103	60.0	D	0		0	51	0		0
104	60.0	D	0		0	52	0		0
105	52.5	N	87.5		16.7	49	2.2	F	18.0
						50	9.1		62.2
106	52.5	N	0		0				
107	52.5	N～D	331.6		63.2	46	0	F	0
						47	0	F	0
108	60.0	D	55.5		9.3	48	0	F	0
109	60.0	D～N	0		0	44	0		0
110	52.5	N	0		0	45	0		0
111	75.0	D	0		0	43	0		0
112	67.5	N～D	0		0	42	0		0
113	60.0	N	0		0				

D: Daytime
N: Nighttime

Mean: 119.68
S. d.: 253.25
S. e.: 23.82

Total: 19769.7

E: Estimate
F: Failure
H: Hard
S: Small
T: Try
○ : Selected operation for estimation

Table 2. Stock biomass index, density index, catch and density of anchovy observed in the 2nd cruise.

Block No.	Distance (mile)	Time	Stock Biomass Index (mm^2)		Density Index (mm^2/10 miles)	St. No.	Catch (Kg)		Density (ton/$mile^3$)
1	38.8	N	0		0	4	0		0
2	38.3	D～N	11.0		2.9	3	0.6		7.6
3	38.8	D～N	4748.9		1223.9	8	543.3		4945.5
4	41.1	N	2948.4	H	717.4	5	238.0		4332.9
5	41.0	D	0.2		0.1	2	0.2		3.2
6	28.5	D	1563.6		548.6	11	2824.2		37056.4
7	38.0	N	3086.2	H	812.2	9	917.0		21176.9
8	40.5	D	426.0		105.2	7	14.9	T	520.8
9	41.7	N～D	1873.6		449.3	6	652.8		8913.4
10	31.2	D	1872.9		600.3	○12	608.2		6872.9
11	38.0	N～D	3286.4		864.8	○10	262.2		3818.8
12	38.8	N	106.5		27.4				
13	38.2	D	113.3		29.7				
14	38.0	N～D	709.5	H	186.7	15	110.0		1300.3
15	38.5	N	3264.1	H	847.8	14	395.6		6145.8
16	38.2	D～N	183.3		48.0				
17	38.2	N	313.8		82.1	20	27.0	T	362.3
18	37.8	N	1415.0		374.3	18	22.5	T	436.9
19	38.2	N	5273.6	H	1380.5	17	669.7		6650.3
20	38.0	D	76.5		20.1				
21	37.8	N	2469.9		653.4	13	457.8		4189.9
22	37.8	D～N	48.5		12.8				
23	44.0	D	1496.1		340.0	○29	249.6		2729.2
24	44.5	D	1983.1		445.6	27	272.1		3651.4
25	37.8	N	61.8		16.3	25	2.5		27.0
26	38.2	N	1081.9	H	283.2	24	47.8	T	522.1
27	37.8	N	5131.1	H	1357.4	21	2135.0		29755.9
28	48.2	D～N	1462.0		303.3	19	891.1		11587.8
29	38.2	N～D	16.3		4.3				
30	38.0	N	55.7		14.7				
31	38.0	D	32.3		8.5				
32	35.0	N	1817.4	H	519.3	40	417.7		6117.2
33	37.8	N	2376.5		628.7	○35	1205.2		16622.1
34	37.5	D	748.1		199.5	○34	171.0		2058.3
35	38.5	D	3120.0		810.4	○30	513.0		7624.0
36	38.0	N	3451.7		908.3	○27	754.8		11104.2
37	38.0	N～D	11.0		2.9				
38	38.0	D～N	10.0	H	2.6	23	0.1		1.2
39	47.2	N～D	308.6	H	65.4	22	6.7		73.9
40	38.0	D	95.1		25.0				
41	37.5	D	112.4		30.0				
42	37.8	D～N	248.0	H	65.6	16	0	F	0
43	37.0	N	375.0	H	101.4	41	0	T	0
44	37.5	D～N	5234.2		1395.8	○39	2432.5		31897.8
45	38.2	N	4743.1		1241.6	○36	270.4		4102.3
46	38.0	D	3954.9		1040.8	○33	1015.4		12604.0
47	38.0	N	463.8	H	122.1	31	187.5		2433.9
48	38.0	N	264.0	H	69.5	26	14.9		212.8
49	38.2	D	3.1		0.8				
50	37.0	D	30.0		8.1				
51	38.0	D	30.0		7.9				
52	37.2	N	155.1	H	41.7	44	2.2	T	26.4
53	38.0	D～N	2053.6		540.4	○43	638.0		6073.2
54	38.2	N～D	84.2		22.0				
55	46.0	D	3397.5		738.6	○38	966.1		7994.7
56	38.0	N～D	5077.5	H	1336.2	37	1159.5		15352.2
57	45.2	N～D	537.1	H	118.8	32	174.9		3032.5
58	38.2	N	217.5		56.9				
59	38.2	D～N	8.6		2.3				
60	36.0	D	8.6		2.4				
61	37.8	D	0		0				
62	42.0	D	1384.6		329.7	○57	215.7		1870.0
63	37.5	N～D	100.0		26.7	56	0	F	0
64	39.0	N	1434.3		367.8	○55	258.0		2277.3
65	37.5	N	22.6	H	6.0	51	1.7	S	15.3
66	39.0	N	4337.3		1112.1	○48	4000.3		48018.0
67	38.0	N	6052.4		1592.7	○47	4177.3		31687.3
68	42.2	N～D	2749.3		651.5	○45	472.4		5265.5
69	37.0	D	1138.1		307.6	○42	191.8		1862.3
70	37.8	D	112.2		29.7				
71	40.0	D	1240.0		310.0	○58	271.1		1922.9
72	37.2	D～N	330.0		88.7				
73	31.0	N	587.0		189.4	59	90.2		663.4
74	36.0	N	1112.3	H	309.0	54	70.7	S	771.5
75	38.0	N	1627.2		428.2	○52	128.1		1211.5
76	37.2	D～N	3575.0		961.0	○50	2145.0		15939.1

Table 2. (continued) — 2nd cruise.

Block No.	Distance (mile)	Time	Stock Biomass Index (mm^2)		Density Index (mm^2/10 miles)	St. No.	Catch (Kg)		Density ton/$mile^3$
77	37.0	N～D	462.1		124.9				
78	38.2	D～N	3109.3		814.0	○46	2413.1		26896.9
79	38.0	D	219.0		57.6				
80	37.0	D	106.6		28.8				
81	34.0	N	28.7	H	8.4	60	3.8		27.7
82	37.2	D～N	440.8		118.5	53	237.9	S	2410.6
83	37.5	N～D	169.6		45.2				
84	37.2	D	272.8		73.3				
85	37.5	D	495.0	H	132.0	49	0	F	0
86	67.5	D	960.9	H	142.4	63	0	F	0
87	37.0	D	420.0		113.5				
88	37.5	N～D	60.0		16.0				
89	37.5	D	150.4		40.1				
90	37.0	D	185.1		50.0				
91	40.0	D	97.4		24.4				
92	34.0	D	1260.0		370.6	64	3948.5		30267.0
93	36.0	N	4770.6		1325.2	○62	5891.4		52234.8
94	47.8	D	435.0	H	91.0	61	0	F	0
95	37.0	N	2000.0		540.5				
96	35.0	D～N	1075.0	H	307.1	65	585.0		4733.4
97	37.0	D～N	221.4		59.8				
98	37.0	D	55.3		14.9				
99	37.0	D	0		0				
100	36.2	N	135.0		37.3	66	58.7		916.0
101	45.0	N～D	1716.1	H	381.4	70	1328.8		10017.1
102	35.0	D	0		0				
103	43.0	D	4.6		1.1	67	3.7		11.3
104	36.5	D～N	214.0	H	58.6	73	168.4		1774.3
105	33.0	D	30.0	H	9.1	71	0	T	0
106	36.8	N	0		0	69	0		0
107	36.8	D～N	10.0		2.7				
108	36.5	D	50.0	H	13.7	76	0		0
109	37.2	D	20.0	H	5.4	75	0		0
110	36.5	N	70.0	H	19.2	74	0		0
111	36.5	D	7.9		2.2				
112	36.8	D	5.0	H	1.4	72	0	F	0
113	36.5	N	15.0	H	4.1	68	0		0
114	36.5	N～D	100.0	H	27.4	79	0	F	0
115	36.5	N	149.1		40.8	78	71.4		472.7
116	36.5	D～N	0.1		0	77	0.5		4.6
117	36.5	N～D	0		0				
118	36.5	N	0		0				
119	31.0	D	0		0				
120	21.2	D	0		0				
121	24.5	D	0.1		0	80	0		0
122	20.5	D～N	0		0				
123	76.3	D	0		0	1	0		0
124	81.0	N～D	4050.0		500.0	○90	2673.2		20491.3
125	77.8	D～N	1444.8		185.7	○89	279.6		2571.9
126	108.7	D	688.9		63.4	○88	152.3		1485.4
127	75.8	D	180.0		23.7				
128	49.2	N	14.7		3.0				
129	66.0	D	215.0	H	32.6	87	0		0
130	26.8	N～D	0		0				
131	75.2	D	199.5		26.5				
132	62.3	N～D	60.4		9.7	86	33.4		304.0
133	52.8	D	34.3		6.5				
134	52.0	N～D	542.2		104.3	83	103.0		1240.0
135	47.5	D	977.5		205.7	○84	157.5		1349.3
136	68.5	N	3545.9		517.6	○85	542.9		5857.0
137	52.8	D	0.2		0				
138	52.0	D～N	0.1		0	82	1.3		10.4
139	66.0	N～D	0.3		0				
140	64.5	N	0.3		0	81	0		0

D: Daytime
N: Nighttime

Mean: 252.55
S. d.: 380.00
S. e.: 32.12

Total: 51948.7

F: Failure
H: Hard
S: Small
T: Try
○: Selected operation for estimation

Table 3. Relationship between density index and density derived from nine trawl operations in the 1st cruise.

Block No.	St. No.	*SBI'* (mm^2)	Actual distance of *SBI'* (mile)	*DI'* (mm^2/10 miles)	Density (ton/$mile^3$)	Density / *DI'*
14	72	70.6	1.5000	470.7	5985.0	12.72
44	15	562.5	1.2500	4500.0	30290.1	6.73
51	24	424.3	5.6884	745.9	4588.3	6.15
52	23	24.3	2.6275	92.5	1129.6	12.21
53	19	52.0	3.4807	149.4	1421.9	9.52
60	26	30.0	2.0000	150.0	3320.6	22.14
64	18	300.0	3.0338	988.9	21400.1	21.64
77	31	175.5	3.1638	554.7	6429.7	11.59
80	32	37.5	3.4380	109.1	2237.0	20.50
					Mean:	13.69
					S. d.:	6.24

large quantities of plankton and salpa*. For this reason *SBI* in these blocks were estimated from densities obtained in the neighboring blocks of Nos. 3 and 6. Namely, density indexes per density of 1 ton/$mile^3$ in block Nos. 3 and 6 were obtained, and their mean value of 0.1270 mm^2/10 miles was used, to calculate back the *SBI*s from the densities obtained by mid-water hauls in the respective blocks. These were specially noted as E(estimate) in Tables 1 and 2.

There were many cases where no fish were caught by mid-water trawl operation although echoes were recorded. These often occurred specially in daytime operations when the swimming layer was shallow, therefore, it seems to be caused by the escape of fishes. These cases were indicated by F(failure) in the catch columns of Tables 1 and 2. Also when recorded echoes were surmised to come from Argentinian hake, salpa and plankton etc., trawl operations were made to confirm the species. The results were indicated as T(try) in these tables. The cod end of fishing gear used was 23 mm meshes, and small anchovy escaped through the meshes. When the net was towed up, visual observation was made, and if there was found any escape, it was indicated as S(small) in Tables 1 and 2. The minimum length of anchovy caught was about 5 cm in fork length.

Estimation of Stock Biomasses

The stock biomass of anchovy cannot be estimated from the density obtained from the trawl operation, because the operations were not made at random, but made only at the places where echo was recorded.

The stock biomasses were estimated by the following two methods. Nine operations of the 1st cruise and 28 operations of the 2nd cruise were selected, which were made successfully, and in which small fishes were not dominated and the echoes were continuously recorded in the whole distance of operation (○ marked station numbers in Tables 1 and 2.) For each block, a density index (*DI'*) was calculated from the stock biomass index (*SBI'*) obtained from the echoes recorded during the hauling, and was compared with the density obtained from the mid-water trawl operation. The results are shown in Tables 3 and 4 by cruise. The ratios of density to *DI'* 1 mm^2/10 miles were varied

* Salpa gives strong echoes in case of low frequency echo sounder.

Table 4. Relationship between density index and density derived from 28 trawl operations in the 2nd cruise.

Block No.	St. No.	*SBI'* (mm^2)	Actual dstance of *SBI'* (mile)	*DI'* (mm^2/10 miles)	Density (ton/$mile^3$)	Density / *DI'*
10	12	105.0	3.5073	299.4	6872.9	22.96
11	10	84.5	2.2438	376.6	3818.8	10.14
23	29	167.3	3.3615	497.7	2729.2	5.48
33	35	1972.2	4.2000	4695.7	16622.1	3.54
34	34	67.6	2.9522	229.0	2058.3	8.99
35	30	100.0	3.4563	289.3	7624.0	26.35
36	27	746.0	2.8781	2592.0	11104.2	4.28
44	39	212.2	1.7188	1234.6	31897.8	25.84
45	36	397.8	4.1559	957.2	4102.3	4.29
46	33	371.7	4.2000	885.0	12604.0	14.24
53	43	118.7	3.6313	326.9	6073.2	18.58
55	38	82.5	3.2615	253.0	7994.7	31.60
62	57	193.8	4.1792	463.7	1870.0	4.03
64	55	209.9	3.1667	662.8	2277.3	3.44
66	48	532.6	1.8125	2938.5	48018.0	16.34
67	47	978.2	3.6667	2667.8	31687.3	11.88
68	45	111.9	3.6385	307.5	5265.5	17.12
69	42	39.6	2.7344	144.8	1862.3	12.86
71	58	90.0	4.3750	205.7	1922.9	9.35
75	52	30.8	2.0000	154.0	1211.5	7.87
76	50	342.8	1.8500	1853.0	15939.1	8.60
78	46	156.6	1.9375	808.3	26896.9	33.28
93	62	514.9	1.5000	3432.7	52234.8	15.22
124	90	350.0	2.8750	1217.4	20491.3	16.83
125	89	49.8	2.8750	173.2	2571.9	14.85
126	88	35.6	3.5000	101.7	1485.4	14.61
135	84	37.5	3.5729	105.0	1349.3	12.85
136	85	147.0	2.7500	534.5	5857.0	10.96
					Mean:	13.80
					S. d.:	8.23

between 6.15 and 22.14 tons/$mile^3$ in the 1st cruise, and between 3.44 and 33.28 in the 2nd cruise, and the respective mean values of 13.69 and 13.80 tons/$mile^3$ were used. The areas investigated were 104,112.0 $mile^2$ in the 1st cruise and 130,767.7 $mile^2$ in the 2nd cruise. Since the range of depths where anchovy were distributed was 40 m on the average (10 to 50 m deep) judging from the recorded echoes, the total

Table 5. Relationship between stock biomass index and catch derived from nine trawl operations in the 1st cruise.

Block No.	St. No.	*SBI"* (mm²) caught	Catch (Kg)	Catch / *SBI"*
14	72	70.6	821.5	11.64
44	15	562.5	3464.7	6.16
51	24	111.9	629.8	5.63
52	23	13.9	180.9	13.01
53	19	22.4	227.7	10.17
60	26	30.0	607.7	20.26
64	18	148.3	2937.4	19.81
77	31	106.8	1132.6	10.60
80	32	30.0	348.0	11.60
			Mean:	12.10
			S. d.:	5.13

volumes where they were distributed were 2,248.6 mile³ in the 1st cruise and 2,824.4 mile³ in the 2nd cruise. The mean *DI* of 113 blocks of 1st cruise was 119.68 mm²/10 miles (standard error 23.82), and the mean *DI* of 140 blocks of 2nd cruise was 252.55 mm²/10 miles (standard error 32.12). Therefore, the stock biomasses of anchovy in the areas investigated can be estimated from equation (4).

1st cruise

$$13.69 \times 2{,}248.6 \times 119.68 = 368.4 \times 10^4 \text{ (tons)}^* \quad (4)$$

2nd cruise

$$13.80 \times 2{,}824.4 \times 252.55 = 984.4 \times 10^4 \text{ (tons)}^* \quad (4)$$

The *SBI"*s surmised to be covered by hauling in the distances hauled are compared with actual catches in Tables 5 and 6 by cruise. The ratios of catch to *SBI"*s 1 mm² were 5.63 to 20.26 being 12.10 kg on the average in the 1st cruise, and 4.05 to 20.59 being 8.18 kg on the average in the 2nd cruise. If the mean depth of fishes is 30 m, the effective breadth*1 applied to the echo sounder is 6.2717 m since the half power beam angle is 6°, and the sailing of 10 miles covers the area of 0.0338645 mile². The stock biomasses can be estimated from equation (5).

1st cruise

$$0.01210 \times (104{,}112.0/0.0338645) \times 119.68 = 445.2 \times 10^4 \text{ (tons)}^{*2} \quad (5)$$

2nd cruise

$$0.00818 \times (130{,}767.7/0.0338645) \times 252.55 = 797.7 \times 10^4 \text{ (tons)}^{*2} \quad (5)$$

The 2nd cruise showed two to three times the stock biomass of 1st cruise. Though details cannot be known by only two times of survey, it is suggested that the seasonal change was caused by the immigration of anchovy from Uruguay waters. Another possibility to explain those differences is the evidence of a movement of the anchovy shoals from coastal waters, where they should be highly concentrated during the 1st cruise, to open and deeper waters during the 2nd cruise. Fishermen's observations should confirm these ideas. Figs. 7 and 8 show the distribution of water temperatures. In the 1st cruise, the intrusion of cold water in the vicinity of 40°S, 58°W divided the distribution area

* 95% confidence interval: 224.7 to 512.2×10^4 tons for 1st cruise and 738.9 to $1{,}229.7 \times 10^4$ tons for 2nd cruise.

* 1 The effective breadth of the echo sounder depends upon the property of the echo sounder, the intensity of echo from the school and the depth of the school. Since these parameters of the echo sounder used in this survey were not measured, any strict description cannot be made. Therefore, in this report, the half power beam angle was used as effective angle.

* 2 95% confidence interval: 271.5 to 618.9×10^4 tons for 1st cruise and 598.8 to 996.6×10^4 tons for 2nd cruise. However, according to Maniwa (1962), the effective angle is about 60% of half power beam angle. In this case, the breadth to be applied is about 3.78 m and the stock biomass estimates are 738.7×10^4 tons and $1{,}358.9 \times 10^4$ tons.

Table 6. Relationship between stock biomass index and catch derived from 28 trawl operations in the 2nd cruise.

Block No.	St. No.	*SBI"* (mm^2) caught	Catch (Kg)	Catch / *SBI"*
10	12	105.0	608.2	5.79
11	10	56.3	262.2	4.66
23	29	41.8	249.6	5.97
33	35	246.5	1205.2	4.89
34	34	33.8	171.0	5.06
35	30	50.0	513.0	10.26
36	27	186.5	754.8	4.05
44	39	159.2	2432.5	15.28
45	36	33.2	270.4	8.14
46	33	139.4	1015.4	7.28
53	43	89.0	638.0	7.17
55	38	61.9	966.1	15.61
62	57	48.5	215.7	4.45
64	55	58.7	258.0	4.40
66	48	399.5	4000.3	10.01
67	47	489.1	4177.3	8.54
68	45	74.6	472.4	6.33
69	42	19.8	191.8	9.69
71	58	42.5	271.1	6.38
75	52	20.1	128.1	6.37
76	50	28.6	145.0	5.07
78	46	117.2	2413.1	20.59
93	62	386.2	5891.4	15.25
124	90	262.5	2673.2	10.18
125	89	35.0	279.6	7.99
126	88	20.7	152.3	7.36
135	84	25.1	157.5	6.27
136	85	90.3	542.9	6.01
			Mean:	8.18
			S. d.:	4.05

into two major parts, and anchovy was distributed in the coastal area of 9.5 to 11.0°C on the 25 m layer, generally. In the 2nd cruise, they distributed mainly in the region of 12 to 14°C on the 30 m layer, and tended to be found in large quantities off the concave parts of the coast line. In future, it is necessary to clear up the relationship between the distribution pattern of anchovy and the oceanographic conditions.

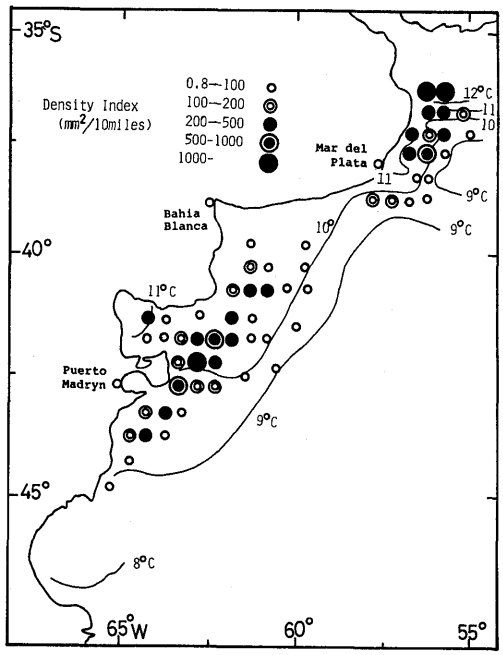

Fig. 7. Distribution of density index of anchovy and water temperature of 25 m layer observed in the 1st cruise.

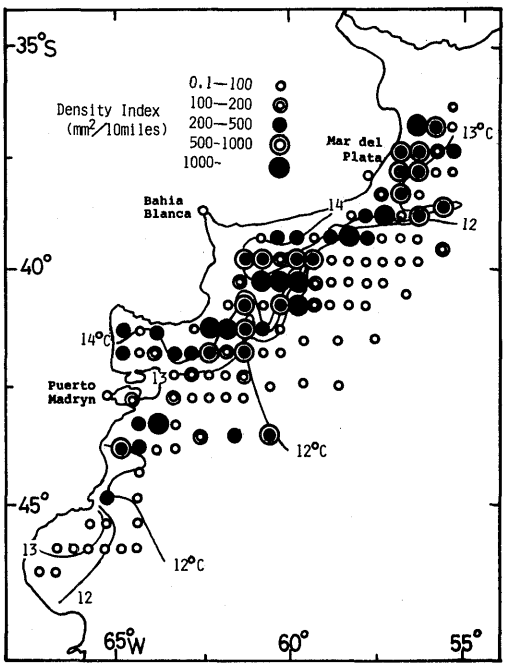

Fig. 8. Distribution of density index of anchovy and water temperature of 30 m layer observed in the 2nd cruise.

Consideration and Future Problems

The estimation of stock biomasses involves some problems. The first problem must be thickness of recorded echo. In this report, the thicknesses of echo were classified into four classes and were weighted empirically by 0.25 to 1.00, respectively, as a practical method. In general, the intensity of echo is proportional to the square root of the number of individuals, and is inversely proportional to the fourth power* of the distance. Usually, the aggregated type of echo appears in deeper layer and the dispersed type appears in shallower layer, therefore, the difference in thickness between aggregated type and dispersed type might be actually larger than the weight used here.

According to the records of net sonde, the area of the mouth of mid-water trawl net used was estimated to 314.2 m^2 (circle of 10 m radius) in the 1st cruise, and 215.9 m^2 on the average (oval, mean net mouth width 16.8 m) in the 2nd cruise, because the float and the otter board were readjusted at the beginning of 2nd cruise. The ratios of density to *DI'* were not so different between both cruises (Tables 3 and 4), but the ratios of catch to *SBI"* were considerably larger with the 1st cruise (Tables 5 and 6). Since the method of equation (4) uses the density obtained from the area of net mouth, it is not concerned with the change in the area of net mouth by readjustment of gear. On the other hand, in the method of equation (5), the catch might be affected by the difference in the area of net mouth. Therefore, the difference of the ratios of catch to *SBI"* between both cruises was probably caused by the adjustment of the gear. When the breadth of the school caught is more than 6.2717 m (effective breadth of echo sounder), equation (5) causes overestimation. With regard to the propriety of estimates by both methods, no information is now available for detailed comparison. In future, a purse seine net must be trially applied as a fishing gear in which the problem of net coefficient is hardly contained.

The structure of fish school and behaviour of anchovy change depending on time, and the net coefficient probably alters between daytime and nighttime. However, the ratios of density to *DI'* and the ratios of catch to *SBI"* were nearly equal between daytime and nighttime operations. Thus, no information is now available concerning the difference of net coefficients, and for covenience, daytime and nighttime operations were combined together. The estimate in this report may be considered as the stock biomass of anchovy that can be caught by the fishing gear and net used in this research.

When a relative density is obtained by calculating a density index (*DI*) from the echoes recorded by echo sounder, sounding in daytime only is ideal, since the echoes of aggregated type are easy to identify and to measure *DI*. However, when it is combined with a catch by mid-water trawl, there is a large problem on decline of net coefficient. On the other hand, in case of nighttime sounding, the net coefficient is stable, but the echoes of dispersed type are often hard to identify, and difficult to measure *DI*. In future, it is desirable to repeat a preliminary survey in day and night within a small area, and to choose better time zone, based upon the schooling behaviour and catchability of the objective species.

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* In the case of single fish.

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魚群探知機によるアルゼンチン陸棚のカタクチイワシ資源量の推定

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アルゼンチン共和国と海洋水産資源開発センターが締結した「漁業調査実行取極め」の一環として，1978年9月21日～10月12日（第1次航海）と11月20日～12月19日（第2次）に深海丸によって実施した．用いた魚探は海上電機のMWB－115型（周波数24KHz，指向角前後3°左右6°，湿式）である．対象水域は両航海とも陸棚上の35°30′～47°S，54°～67°30′Wの主として100m以浅で，面積は約10万mile²である．対象水域を沿岸側は30′×30′の小格子に，沖合側は1°×1°の大格子にわけ，通常は格子の対角線上を航走するように調査線を設定した．魚種判定と資源量推定のため調査線上で中層曳トロール網操業を72回と90回実施した．調査は昼夜兼行で，1航程は約5千mileであった．

平均13ノットで航走中の魚探の全記録像のうち，カタクチイワシと思われるものについてそれぞれ面積を計測した．昼夜の集群生態の差を少なくするため，記録像ごとに4段階の濃度による重みづけを行い，魚群量指数（ＳＢＩ）を求めた．一つの格子ごとに走査10mileあたりのＳＢＩを計算し，魚群量密度の相対分布指数とした（魚群量密度指数ＤＩ）．カタクチイワシ魚群の密度(D)を漁獲量・曳網速度（時間）・網口面積より操業ごとに計算した．〔A法〕操業が円滑にいき，魚群の幅が実際の曳網距離以上であったいくつかの操業を選び出し，操業試験から求めたDと曳網した記録像から求めたＤＩとの平均比を算出した．この比と全格子の平均ＤＩおよび分布可能な全体積をかけあわせた．〔B法〕実際の漁獲量と，曳網距離内にあり入網したと推測されるＳＢＩとの比を求め，この比に全格子の平均ＤＩと対象水域の全面積をかけあわせたものを走査10mileの魚探入力有効面積で除した．1次航海はA法368.4×10^4，B法445.2×10^4トン，2次航海はA法984.4×10^4，B法797.7×10^4トンという推定値が得られた．

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